Version With Markings To Show Changes Made

In the Specification

The paragraph beginning on page 2, line 21 has been amended as set forth below:

JVC has also developed a new family of vertically aligned LCDs, which are directly addressed via a silicon backplane (LCOS), rather than indirectly by a CRT. While these new devices are promising, they have not yet been demonstrated to fully meet the expectations for digital cinema presentation. The JVC LCD devices are described, in part, in U.S. Patents Nos. 5,652,667 (Kuragane); 5,767,827 (Kobayashi et al.); and 5,978,056 (Shintani et al.) In contrast to early twisted nematic or cholesteric LCDs, vertically aligned LCDs promise to provide much higher modulation contrast ratios (in excess of 2,000:1). U.S. Patent No. 5,620,755 (Smith et al.), also assigned to JVC, specifically describes a methodology for inducing vertical alignment in LC displays. It is instructive to note that, in order to obtain on screen frame sequential contrast of 1,000:1 or better, the entire system must produce >1000:1 contrast, and both the LCDs and any necessary polarization optics must each separately provide ~2,000:1 contrast. Notably, while polarization compensated vertically aligned LCDs can provide contrast >20,000:1 when modulating collimated laser beams, these same modulators may exhibit contrasts of 500:1 or less when modulating collimated laser beams without the appropriate polarization compensation. Modulation contrast is also dependent on the spectral bandwidth and angular width (F#) of the incident light, with contrast generally dropping as the bandwidth is increased or the F# is decreased. Modulation contrast within LCDs can also be reduced by residual de-polarization or mis-orienting polarization effects, such as thermally induce[s] stress birefringence. Such effects can be observed in the far field of the device, where the typically observed "iron cross" polarization contrast pattern takes on a degenerate pattern.

The paragraph beginning on page 10, line 16 has been amended as set forth below:

Figure 5a shows the geometry of incident light relative to the wire grid polarizing beamsplitter and an LCD [within a modulation optical system, illustrating both polarization states and the local beam geometry].

The paragraph beginning on page 13, line 16 has been amended as set forth below:

The preferred spatial relationships of these polarizers, as used in a modulation optical system 200, are illustrated in Figure 3. The basic structure and operation of modulation optical system 200 are described in commonly-assigned copending U.S. Patent Application Serial No. 09/813,207, filed March 20, 2001, entitled DIGITAL CINEMA PROJECTOR, by Kurtz et al., the disclosure of which is incorporated herein. Modulation optical system 200, which is a portion of an electronic projection system, comprises an incoming illumination light beam 220, focused through pre-polarizer 230, wire grid polarization beamsplitter 240, a compensator 260, and onto spatial light modulator 210 (the LCD) by a condensor 225. A modulated, image-bearing light beam 290 is reflected from the surface of spatial light modulator 210, transmitted through compensator 260, reflected off the near surface of wire grid polarization beamsplitter 240, and is subsequently transmitted through a polarization analyzer 270. After leaving modulation optical system 200, modulation image bearing light beam 290 follows along optical axis 275, and is transmitted through recombination prism 280 and projection lens 285 on its way to the screen. Pre-polarizer 230 and polarization analyzer <u>270</u> are assumed to both be wire grid polarization devices. A full color projection system would employ one modulation optical system 200 per color (red, green, and blue), with the color beams re-assembled through the recombination prism 280. Condensor 225, which will likely comprise several lens elements, is part of a more extensive illumination system which transforms the source light into a rectangularly shaped region of nominally uniform light which nominally fills the active area of spatial light modulator 210.

The paragraph beginning on page 14, line 7 has been amended as set forth below:

In a modulation optical system 200 utilizing a prior art wire grid polarization beamsplitter, the wire grid polarization beamsplitter 240 consists of a dielectric substrate 245 with sub-wavelength wires 250 located on one surface (the scale of the wires is greatly exaggerated). Wire grid polarization beamsplitter 240 is disposed for reflection into projection lens system 285, thereby avoiding the astigmatism and coma aberrations induced by transmission through a tilted plate. Compensator 260 is nominally a waveplate which provides a small amount of retardance needed to compensate for geometrical imperfections and birefringence effects which originate at the surface of spatial light modulator 210. For example, as discussed in U.S. Patent 5,576,854 ([Smith] <u>Schmidt</u> et al), compensator 260 may provide 0.02 λ's of retardance (A-plate) to correct for polarization errors caused by residual geometrical imperfections of the LCD polarizing layer and residual thermally induced birefringence within the counter electrode substrate within the LCD package. In less demanding applications than digital cinema, compensator 260 may prove optional.

The paragraph beginning on page 29, line 10 has been amended as set forth below:

A third example compensator was designed, in this case to enhance the contrast provided by wire grid [polarizing] <u>polarization</u> beamsplitter 240, as used in the modulation optical system 200 of Figure 10 along with spatial light modulator 210 (VA LCD). This compensator example has a combination of an A-plate and a C-plate, having retardations of 90 nm and 320 nm (both with positive birefringence), respectively. Within the layered structure of the compensator, the A-plate is preferentially located closer to the wire grid polarization beamsplitter than the C-plate, which is closer to the LCD. The optical axis of A-plate is parallel to the transmission axis of the adjacent polarizer (perpendicular to the wires). Figure 8h shows the combined transmission through a wire grid polarizing beamsplitter used in combination with this compensator is reduced to 2.7×10^{-2} compared to 6.5×10^{-2} at a polar angle of 30 degrees in Figure 8g. Even at smaller polar angles, such as 15 or 20 degrees, the compensator reduces transmission (less leakage) by ~2x as compared to the un-compensated wire grid polarization beamsplitter. This compensator is shown in the modified

modulation optical system 200 of Figure 10 as compensator 260, and is located between wire grid polarization beamsplitter 240 and liquid crystal spatial light modulator 210. This is the only acceptable location for this compensator within modulation optical system 200.

The paragraph beginning on page 29, line 28 has been amended as set forth below:

A fourth example compensator was designed, as with the last exemplary device, to enhance the combined transmission provided by wire grid [polarizing] <u>polarization</u> beamsplitter 240 used in the modulation optical system 200 of Figure 10 along with spatial light modulator 210 (VA LCD). This compensator is a combination of A-plate and C-plate having a retardation of 90 nm and -200 nm, respectively (positive and negative birefringence). The compensator of Figure 8i provides a smaller combined transmission, which is $3.5x10^{-2}$ compared to $6.5x10^{-2}$ in Figure 8g. Unlike the third example compensator, the optical axis of the A-plate for this compensator is perpendicular to the transmission axis of the adjacent polarizer (parallel to the wires), rather than parallel to the transmission axis (perpendicular to the wires). As before, this compensator is shown in the modified modulation optical system 200 of Figure 10 as compensator 260.

The paragraph beginning on page 34, line 3 has been amended as set forth below:

Figure 4 shows a graph <u>of the compensated contrast</u> 310 that relates system contrast to the relative F# for a modulation optical system comprising a VA LCD, wire grid polarizers, a wire grid polarization beamsplitter, and a compensator, which correct for the unwanted P polarization in returning modulated beam. In this case, a customized version of compensator 260 is used. Notably, although use of a compensator can actually reduce CR at higher F# values, the compensator improves contrast at low values, below approximately F/4.0. <u>Note that compensated contrast</u> [Contrast] 310 may not always be better, because compensators can be complex structures, which <u>can</u> suffer undesired reflections and defects.

The Parts List beginning on page 35 has been amended as set forth below:

10. Digital projection apparatus
15. Light source
20. Illumination optics
40. Modulation optical system
45. Pre-polarizer
50. Wire grid polarization beamsplitter
55. Spatial light modulator
60. [Parization] Polarization analyzer
70. Projection optics
75. Display surface
100. Wire grid polarizer
110. Conductive electrodes or wires
120. Dielectric substrate
130. Beam of light
132. Light Source
140. Reflected light beam
150. Transmitted light beam
200. Modulation optical system
210. Spatial light modulator (LCD)
220. Illumination light beam
225. Condensor
230. Wire grid pre-polarizer
240. Wire grid polarization beamsplitter
245. Dielectric substrate
250. Sub-wavelength wires
260. Compensator
265. Secondary compensator
266. Alternate secondary compensator
270. Wire grid polarization analyzer
275. Optical axis

285. Projection lens

280. Recombination prism

290. Modulated image-bearing light beam

300. System contrast

310. Compensated contrast [Graph]

320. Iron Cross pattern

325. Baseball pattern

350. Pre-polarized beam

355. Transmitted beam

360. Modulated beam

365. Leakage light

370. Transmitted light

400. Multi-layer compensator

410a. Birefringent layers

410b. Birefringent layers

410c. Birefringent layers

420. Substrate

In the Claims

Claim 1 has been amended as set forth below:

1. (Amended) A display apparatus comprising:

(a) a light source for forming a beam of light;

(b) a pre-polarizer for polarizing said beam of light to provide a polarized beam of light;

(c) a wire grid [polarizing] polarization beamsplitter for receiving said polarized beam of light, for transmitting said polarized beam of light having a first polarization, and for reflecting said polarized beam of light having a second polarization;

(d) a reflective liquid crystal device for selectively modulating said polarized beam of light having a [second] first polarization to encode image data thereon in order to form a modulated beam, and for reflecting said modulated beam back to said wire grid [polarizing] polarization beamsplitter;

(e) a compensator, located between said wire grid polarization beamsplitter and said reflective liquid crystal device, for conditioning oblique and skew rays of said modulated beam to provide a compensated modulated beam;

(f) wherein said wire grid [polarizing] polarization beamsplitter reflects said compensated modulated beam;

(g) a polarization analyzer which removes residual light of the opposite [unmodulated first] polarization [light]; and

(h) image-forming optics for forming an image from said compensated modulated beam.

Claim 7 has been amended as set forth below:

7. (Amended) A modulation optical system for providing high contrast modulation of an incident light beam, comprising:

(a) a pre-polarizer for pre-polarizing said beam of light to provide a polarized beam of light;

(b) a wire grid polarization beamsplitter for receiving said polarized beam of light, for transmitting said polarized beam of light having a first polarization, and for reflecting said polarized beam of light having a second polarization;

(c) a reflective liquid crystal device for selectively modulating said polarized beam of light having a first polarization to encode image data thereon in order to form a modulated beam, and for reflecting said modulated beam back to said wire grid [polarizing] polarization beamsplitter;

(d) a compensator, located between said wire grid polarization beamsplitter and said reflective liquid crystal device, for conditioning oblique and skew rays of said modulated beam to provide a compensated modulated beam;

(e) a polarization analyzer which removes residual light of the opposite [unmodulated first] polarization [light].

Claim 13 has been amended as set forth below:

13. (Amended) A modulation optical system for providing high contrast modulation of an incident light beam, comprising:

(a) a wire grid pre-polarizer for pre-polarizing said beam of light;

(b) a wire grid polarization beamsplitter for receiving said polarized beam of light, for transmitting said polarized beam of light having a first polarization, and for reflecting said polarized beam of light having a second polarization;

(c) a reflective liquid crystal device for selectively modulating said polarized beam of light having a first polarization to encode image data thereon in order to form a modulated beam, and for reflecting said modulated beam back to said wire grid [polarizing] polarization beamsplitter;

(d) a compensator, located between said wire grid polarization beamsplitter and said reflective liquid crystal device, for conditioning oblique and skew rays of said modulated beam to provide a compensated modulated beam; and

(e) a wire grid polarization analyzer which removes residual light of the opposite [unmodulated first] polarization [light].

Claim 19 has been amended as set forth below:

19. (Amended) A modulation optical system for providing high contrast modulation of an incident light beam, comprising:

(a) a wire grid pre-polarizer for pre-polarizing said beam of light;

(b) a wire grid polarization beamsplitter for receiving said polarized beam of light, for transmitting said polarized beam of light having a first polarization, and for reflecting said polarized beam of light having a second polarization;

(c) a reflective liquid crystal device for selectively modulating said polarized beam of light having a first polarization to encode image data thereon in order to form a modulated beam, and for reflecting said modulated beam back to said wire grid [polarizing] polarization beamsplitter;

(d) a wire grid polarization analyzer which removes unmodulated first polarization light; and

(e) a compensator which conditions oblique and skew rays relative to said wire-grid polarization analyzer and said wire grid pre-polarizer.

Claim 26 has been amended as set forth below:

26. (Amended) A modulation optical system for providing high contrast modulation of an incident light beam, comprising:

(a) a wire grid pre-polarizer for pre-polarizing said beam of light;

(b) a transmissive liquid crystal device for selectively modulating said polarized beam of light having to encode image data thereon in order to form a modulated beam;

(c) a wire grid polarization analyzer which transmits said modulated beam and blocks <u>light of the opposite polarization</u> [and unmodulated beam]; and

(d) a compensator located between said <u>wire grid pre-polarizer</u> [transmissive liquid crystal device] and said wire grid polarization analyzer which conditions oblique and skew rays.

Claim 33 has been amended as set forth below:

33. (Amended) A display apparatus comprising:

(a) a light source for forming a beam of light;

(b) a wire grid pre-polarizer for polarizing said beam of light to provide a polarized beam of light;

(c) a wire grid [polarizing] <u>polarization</u> beamsplitter for receiving said polarized beam of light, for transmitting said polarized beam of light having a first polarization, and for reflecting said polarized beam of light having a second polarization;

(d) a reflective liquid crystal device for selectively modulating said polarized beam of light having a first polarization to encode image data thereon in order to form a modulated beam, and for reflecting said modulated beam back to said wire grid [polarizing] <u>polarization</u> beamsplitter;

(e) a compensator, located between said wire grid polarization beamsplitter and said reflective liquid crystal device, for conditioning oblique and skew rays of said modulated beam to provide a compensated modulated beam;

(f) a wire grid polarization analyzer which removes residual light of the opposite [unmodulated first] polarization [light]; and

(g) image-forming optics for forming an image from said compensated modulated beam.

Claim 39 has been amended as set forth below:

39. (Amended) A display apparatus comprising:

(a) a light source for forming a beam of light;

(b) a wire grid pre-polarizer for polarizing said beam of light to provide a polarized beam of light;

(c) a wire grid [polarizing] polarization beamsplitter for receiving said polarized beam of light, for transmitting said polarized beam of light having a first polarization, and for reflecting said polarized beam of light having a second polarization;

(d) a reflective liquid crystal device for selectively modulating said polarized beam of light having a first polarization to encode image data thereon in order to form a modulated beam, and for reflecting said modulated beam back to said wire grid [polarizing] polarization beamsplitter;

(e) a first compensator located between said wire grid polarization beamsplitter and said reflective liquid crystal device, for conditioning oblique and skew rays of said modulated beam to provide a compensated modulated beam;

(f) a wire grid polarization analyzer which removes residual light of the opposite [unmodulated first] polarization [light];

(g) a second compensator for conditioning oblique and skew rays of said wire grid [polarizing] polarization beamsplitter relative to said wire grid polarization analyzer and said wire grid pre-polarizer; and

(h) image-forming optics for forming an image from said compensated modulated beam.

Claim 43 has been amended as set forth below:

43. (Amended) A method for projecting an image generated from image data, the method comprising:

(a) providing a polarized light beam;

(b) directing said polarized light beam to a wire grid [polarizing] polarization beamsplitter, said beamsplitter transmitting incident light having a first polarization as a transmitted beam, and reflecting incident light having a second polarization as a reflected beam;

(c) modulating said transmitted beam from said wire grid [polarizing] polarization beamsplitter to encode image data at a reflective liquid crystal device and to provide a modulated beam;

(d) disposing a compensator in the path of said modulated beam to remove leakage light from said modulated beam; and

(e) projecting said modulated beam to form said image.

Claim 44 has been amended as set forth below:

44. (Amended) A display apparatus comprising:

(a) a light source for forming a beam of light;

(b) a wire grid pre-polarizer for polarizing said beam of light to provide a polarized beam of light;

(c) a wire grid [polarizing] polarization beamsplitter for receiving said polarized beam of light, for transmitting said polarized beam of light having a first polarization, and for reflecting said polarized beam of light having a second polarization;

(d) a reflective liquid crystal device for selectively modulating said polarized beam of light having a first polarization to encode image data thereon in order to form a modulated beam, and for reflecting said modulated beam back to said wire grid [polarizing] polarization beamsplitter;

(e) a wire grid polarization analyzer which removes residual light of the opposite [unmodulated first] polarization [light];

(f) a compensator for conditioning oblique and skew rays from said wire grid pre-polarizer and said wire grid polarization analyzer; and

(g) image-forming optics for forming an image from said modulated beam.

Claim 51 has been amended as set forth below:

51. (Amended) A display apparatus comprising:

(a) a light source for forming a beam of light;

(b) a pre-polarizer for polarizing said beam of light to provide a polarized beam of light;

(c) a wire grid [polarizing] polarization beamsplitter for receiving said polarized beam of light, for transmitting said polarized beam of light having a first polarization, and for reflecting said polarized beam of light having a second polarization;

(d) a reflective liquid crystal device for selectively modulating said polarized beam of light having a first polarization to encode image data thereon in order to form a modulated beam, and for reflecting said modulated beam back to said wire grid [polarizing] polarization beamsplitter;

(e) a wire grid polarization analyzer which removes residual light of the opposite [unmodulated first] polarization [light];

(f) image-forming optics for forming an image from said modulated beam; and

(g) a compensator, located between said wire grid [polarizing] polarization beamsplitter and said reflective liquid crystal device for conditioning oblique and skew rays of said modulated beam.

Claim 52 has been amended as set forth below:

52. (Amended) A display apparatus comprising:

(a) a light source for forming a beam of light;

(b) a pre-polarizer for polarizing said beam of light to provide a polarized beam of light;

(c) a wire grid [polarizing] polarization beamsplitter for receiving said polarized beam of light, for transmitting said polarized beam of light having a first polarization, and for reflecting said polarized beam of light having a second polarization;

(d) a reflective spatial light modulator for selectively modulating said polarized beam of light having a first polarization to encode image data thereon in order to form a modulated beam, and for reflecting said modulated beam back to said wire grid [polarizing] polarization beamsplitter;

(e) a compensator, located between said wire grid polarization beamsplitter and said reflective spatial light modulator, for conditioning oblique and skew rays of said modulated beam to provide a compensated modulated beam;

(f) wherein said wire grid [polarizing] polarization beamsplitter reflects said compensated modulated beam;

(g) a polarization analyzer which removes residual light of the opposite [unmodulated first] polarization [light]; and

(h) image-forming optics for forming an image from said compensated modulated beam.

Claims 53 and 54 are new.